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Characteristic Features of the Water-Treatment System Design for Outdoor Pools in the Urals

I.A. Arkanova[a,]*, K.A. Kuznetsova[a]

[a] *South Ural State University, 76, Lenin Avenue, Chelyabinsk, 454080, The Russian Federation*

Abstract

Outdoor pools for all-season use in the Urals make it possible to develop optimal conditions for population health promotion and recreation. The operational reliability of a pool involves designing and building of the pool basin structure as well as the modern water treatment that enables conditioning and purification of water from all kinds of contaminants received by water from the external sources and customers including water disinfection. This is achieved by means of development of the water recycling system with the use of filters loaded by the local filtering materials, the use of the combined water disinfection by liquid chlorine-containing reagents and by ozonation, water heating to desired temperatures in summer and in winter. The filter scouring water is intended for car wash after suitable decontamination. Reduction of water discharge for replenishing of the water-treatment system is possible thanks to ozonation and allowance for time estimation of operative and idle periods. These measures decrease the construction costs for such objects and shorten the payback period, attract investors for the project implementation.

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Keywords: outdoor pool; all-season use; filters; filter load; scouring water; combined disinfection; water heating; water balance.

Population health promotion in the Urals, where the principal industrial plants are located, involves solutions for many social problems. In order to develop water sports, health recuperation and cure for adults and children, active family recreation, the building of training and health pools has gained great importance.

At present the Federal party project "500 pools" is in operation; it was initiated by the President of the Russian Federation V.V. Putin at the conference in Vladimir City on October 1, 2009. The project has been carried out since

* Corresponding author.Tel.: +7-951-445-8176.
E-mail address: waterbas@mail.ru

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2010 in association with the Ministry of Education and Science of the Russian Federation, since 2013 in association with the Ministry of Public Health of the Russian Federation.

Designing and building of pools in Russia is undertaken according to Sanitary Regulations and Norms 2.1.2.188-03, State Standards 53491.1-2009, 53491.1-2012, which are on the level of world standards [1-8].

For the Urals the outdoor pool building for all-season use is a timely project. The advantage of such facilities is the greater exposure to natural surroundings, which favors active recreation and health promotion. Swimming in an outdoor pool represents more active recreation and health promotion than similar activities in closed areas. When a roofed pool is built, it is necessary to plan the building with appropriate lighting and ventilating equipment, which leads to the significant cost increase for construction and maintenance, as well as to the extension of the payback period [9-12].

One of the first outdoor pools for all-season use was designed and built in "Uvildy" sanatorium in Chelyabinsk region, it was brought to attention of the Urals population and all Russia, besides. This experience helped us to determine the most important points, that is, characteristic features that should be taken into account not only at primary data acquisition for planning such engineering jobs, but also in the project itself.

When the pools are designed, it is necessary to take into account the technical requirements for the engineering networks for water treatment, the structure does not always have the necessary electric and thermal power supply; the problems exist in connection with water supply deficit, evacuation of the scouring water and the pool discharge water.

The difficulties about the outdoor pool design arise from more intensive water pollution (leaves, twigs, dust, and small debris), it calls for more elaborate water treatment, the necessity to protect the basin structure from frost penetration in winter, as well as safety precautions against accidental falling into water for non-swimmers [13-15].

The modern regulatory documents do not fully allow for specific characteristics connected with the design of outdoor pools.

Academician B.N. Laskorin formulated three general criteria of the modern industrial technology: efficiency, multipurpose use of raw materials, environmental protection.

Any technology can be considered modern only when it helps to solve the problems of efficiency and quality, at the same time ensuring the conditions of environmental protection.

In order to develop the projects for outdoor pools in the Urals, with due consideration for criteria of the modern technology, it is necessary to take into account the following factors:

- for all-season use of a pool the construction of a basin structured to guarantee the full-featured use: the possibility of lap swimming, together with a wing with the good visual space to carry out health promotion routines (water massage, air-to-water massage, the use of recreational facilities), the possibility for people with limited mobility to attend the pool;
- for proper functioning of the water treatment system the provision of thermal and electric power supply with the reserve to ensure water temperature on the level 35-38 °C in winter;
- for meeting the water quality requirements designing filters into a pool, with the use of local filtering materials and of new materials, such as the low-maintenance green glass sand with enhanced technological parameters [16];
- for water disinfection the joint chlorination and ozonation, which provides simultaneous disinfection and chemical purification, oxidation of nitrite, hydrogen sulfide and other contaminants, inevitably received by the pool water from the customers. At the same time the esthetic requirements for water are met, the organoleptic properties of water are improved, and oxygenation takes place;
- for reduction of water discharge for replenishing the time estimation of operative and idle periods, when the pool if free of customers, mostly at night, and the registration of temperature change in the daytime and nighttime hours, in summer period;
- for the scouring water and the pool discharge water the development of facilities for regulation of water collection and purification, as well as its use for technical needs (cleaning of grounds and parking lots, organization of car wash);
- for import substitution the maximal use of domestic equipment, built-in parts, reagents, filtering materials for pool water treatment.

Subsequent to the results of literature review and experience in designing pools of various functions we have suggested the abovementioned approaches and have made the balance of water consumption and discharge for the projected outdoor pool for all-season use in Chelyabinsk region, in a recreational center under reconstruction in order to provide holiday-makers with modern services.

The pool is of intricate shape, its basic part is rectangular for ease of lap swimming, with two attached wings, circular in plan, including the massage zone and the rest zone; it fits the environment with regard to landscape and buildings. The pool is located at the distance of 15 m from the building that should contain the main water treatment facilities in the basement part, according to the planned design.

The primary focus has been directed to the calculation and the choice of filtering installations, as well as the water heating and disinfecting systems in the pool.

According to the calculation the pool requires two filtering units, each of 60 m3/h productivity. In order to meet the water quality requirements in the pool the most critical operation modes have been taken into consideration (the most heavy-duty service). They include change in weather conditions (high wind, storm, downpour), hosting holiday celebrations, aquatic discotheques, etc., which keeps water quality on the required level if the third (reserve) filtering unit is switched on.

The use of local filtering material has been suggested for loading the filters. The official authorization has been obtained from the regional inspectorate of State Committee for Sanitary and Epidemiological Oversight to use the following materials for water treatment:

- quartz sand of "Miass pond" deposit;
- quartz sand of Novo-Sineglazovo deposit;
- quartz grit of Astafievo deposit;
- quartz grit of Larino deposit.

The natural quartz sands of the Urals region contain the large amount of fine fractions and can be used to load filtering installations of utility and drinking water systems. All investigated sands have sufficient mechanical strength and chemical stability [17-20].

The green glass sand AFM is an alternative to sand loading, it does not require changing, being practically inert to bacterial attack, also it is not prone to biofilm formation. The AFM material removes 90% particles up to 5 μm, it has catalytic properties, decomposing oxygen molecules with production of free oxygen radicals; thanks to this self-cleaning takes place. Besides, the material is not subject to clumping of grains, its filter area does not diminish with time like sand filter area.

It has been suggested to collect the scouring water of the filters into special-purpose tanks with the volume 3 m3 and to direct it to car wash for further use. The parking place to accommodate 100 passenger cars is planned for the completed object, where the car wash is logically placed.

In order to ensure the appropriate sanitary state the pool water should be safe, that is, capable of eliminating introduced bacterial contamination.

Joint use of sodium hypochlorite in liquid solution and ozone for outdoor pools permits to benefit from advantages of both reagents. Thus, the use of sodium hypochlorite imparts bactericidal properties to water over a long period of time; the automated dosage and the residual chlorine control practically eliminate irritation of skin and mucous membranes. In its turn, ozone improves physical and organoleptic properties, namely, decoloration and deodorization. Ozone is destructive to aqueous organic compounds, bacteria, spores, viruses. Ozone is more effective than chlorine in eliminating spores and destroying thick cell walls of unicellar organisms, microalgae and protozoa. The use of ozone helps to reduce water discharge for replenishing the circulating water system that should function uninterruptedly during the pool operative time at the rate not less than 50 L per customer, while with ozonation it is not less than 30 L per customer [1, 4, 5]. As ozone is used in outdoor pools, its low maximum permissible concentration in air – not more than 0.1 mg/m3 – is not a drawback, unlike roofed pools, where the air quality should be controlled in the spaces with customers present.

To choose the source of water supply for the pool (utility and drinking water system or blowing well), it is necessary to have the data about total pool water loss, which are calculated as the loss caused by swimmers' splashes, water discharge for replenishing with allowance made for a decontamination method and evaporation from

the water surface. At present the specification for pool replenishing is 10% of pool capacity per day, which makes up to 40 m3/day for the considered volume.

In the daytime (operative time period) the intensity of evaporation from the pool water surface equals [21, 22]:

$$W = \left[0.118 + \left(0.01995 \cdot a \cdot \frac{P_B - P_L}{1.333} \right) \right] \cdot A$$

where W is the intensity of water evaporation;

a is an empiric coefficient, equaling 0.5 for great public pools;

PB is the pressure of water vapors of saturated air in a pool, mbar;

PL is the partial pressure of water vapors at the given temperature and relative humidity of air, mbar;

A is the area of water surface, m2.

At night (idle time period) the intensity of evaporation from the pool water surface equals [21, 23]:

$$W = \left[-0.059 + \left(0.0105 \cdot \frac{P_B - P_L}{1.333} \right) \right] \cdot A \quad (1)$$

The calculation of replenishing with regard to the operative and idle time periods is 65.5 kg/h and 8.85 kg/h, which makes up to:

$$0.786 + 0.1062 = 0.89\, m^3 / day \quad (2)$$

The replenishing losses are determined according to the following formula, taking into account the ozonation method:

$$Q = 0.03 \cdot N \cdot t \quad (3)$$

where N is the basin capacity per hour, determined by the formula [1, 4]:

$$N = \frac{60 \cdot A}{a \cdot t} \quad (4)$$

where A is the area of water surface, m2;

a is the allowance of water surface area per 1 customer, taken as 5 m2;

t is the duration time in a pool, taken as 60 min.

$$N = \frac{60 \cdot 328}{5 \cdot 60} = 66\, person / hour \quad (5)$$

According to Sanitary Regulations and Norms 2.1.2.188-03 hygienic requirements for design, maintenance and water quality for swimming pools demand the replenishing of water decontaminated by chlorine and ozone should amount to not less than 30 L/day per 1 person.

$$Q = 0.03 \cdot 66 \cdot 10 = 19.8\, m^3 / day \quad (6)$$

The losses caused by swimmers' splashes [1, 4]:

$$Q_{spl} = \frac{0.036 \cdot V_{spl}}{t_{oper}} \tag{7}$$

$$Q_{spl} = \frac{0.036 \cdot 400}{10} = 1.44\, m^3 / day \tag{8}$$

Water discharge for replenishing:

$$0.89 + 19.8 + 1.44 = 22.12\, m^3 / day \tag{9}$$

This approach to calculation permits to evaluate water discharge needed for the considered project. According to the calculation it equals 55% of the recommended value that is taken as 10% of the pool volume.

The most important question is the determination of the required thermal power supply to keep the temperature of the pool water at 28°C in summer and at 38°C in winter.

The total capacity of heat exchangers is determined with regard to the pool volume, the given temperature of the pool water, the temperature of filling water, the area of water surface, the time needed to heat water to the given temperature, the factor for heat loss during water heating without heat-saving roofing. It has been found that for the outdoor pool for all-season use in the Urals four 170 kW heat exchangers are needed, and one in reserve. The total power equals 850 kW. Additional two electric water heaters are designed as emergency reserve.

The dosage of liquid coagulant is determined by the manufacturer, as it depends on percent content of the active components; estimated content of Al2O3 (active component) is 20.0%.

For disinfection of water in automatic mode the following basic equipment is necessary:

- metering and regulating unit that measures physical and chemical parameters of water, compares them to the set parameters and gives command signals to dosing plants in the case of difference between the set and actual measurements;
- the dosing plant for correction of pH value;
- the dosing plant for disinfecting agent.

Correction of pH value within the range 7.2–7.8, at which the maximal disinfecting effect is reached, is carried out by acidification of water.

According to standards for pool water disinfection with hypochlorites the dose should amount to 1 mg/L. The joint disinfection method makes it possible to decrease reagent consumption, to lower the level of residual chlorine to 0.3 mg/L, consequently to improve the quality of water.

The material, equipment, reagents for the pool operation must be included in the "List of materials, reagents and compact pollution control facilities, authorized by the State Committee for Sanitary and Epidemiological Oversight of the Russian Federation; for use in utility and drinking water supply".

Conclusions

In order to design outdoor pools in the Urals the following factors should be taken into consideration: climatic conditions, enhanced contamination of water and heat loss compared to roofed pools, purpose of a pool, methods to improve reliability, pool water treatment with regard to energy- and resource-saving practices to meet hygienic requirements for design, maintenance and water quality, with the use of domestic equipment and filtering materials.

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